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RTCA Special Committee 186, Working Group 5

ADS-B UAT MOPS

Meeting #12

Draft #1 of Proposed Appendix K:
UAT System Performance Simulation Results
for
Review in Washington

Presented by Larry Bachman

SUMMARY
This is Draft #1 of Proposed Appendix K of the UAT MOPS for review at the meeting in Washington DC.

Appendix K

UAT System Performance Simulation Results

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K.1 Introduction

K.1.1 Background

Analytical models and detailed simulations of data links operating in future scenarios are required to assess expected capabilities in stressed circumstances. Accurately modeling future capabilities for potential system designs in a fair way, however, is challenging. Since validation of simulation results in future environments is unrealistic, other means of verification such as the following are required. System characteristics represented in these simulations should agree with actual measurements on components of the proposed design, e.g., bench measurements on prototype equipment and calibrated flight test data should be used, when possible, for the receiver/decoder capabilities and as comparison with modeled link budgets. Similarly, suitable interference models help to support estimates of how these conditions may change in future scenarios. Credibility of any simulation results for future scenarios also requires that they be able to model current conditions and provide results that appropriately agree with measurements made under these conditions. Existing tools have been used as cross-checks where possible for the final detailed simulations and models.

K.1.2 General Assumptions

In an effort to capture as many real-world effects important to the assessment of the performance of UAT as possible, an attempt was made to include, to the extent possible, representations of the effects of:

- Propagation and other losses
- Antenna gains
- Propagation delays
- Co-channel interference (specifically, DME/TACAN and Link 16)
- Co-site interference (in and out of band)
- Multiple (self) interference sources
- Alternating transmissions between top and bottom antennas (where applicable)
- Performance as a function of receiver configuration
- Transmit power variability
- Receiver retriggering
- FIS-B transmissions
- Receiver performance based on bench testing
- Message transmission sequence and information content by aircraft equipage

K.1.3 UAT Detailed Simulation Description and Limitations

The UAT detailed simulation is written in C and allows for horizontal, constant-velocity motion of the aircraft in the scenario, if the user so chooses. The simulation reads in the inputs specifying the particular case to be run, generates all of the ADS-B transmissions and interference, calculates levels and times of arrival for these transmissions, and determines the corresponding message error rates for each ADS-B transmission by all aircraft within line of sight of the victim receiver. This information is then written to an output file, one entry line for each ADS-B transmission, which is then analyzed by post-simulation software. Each of the effects listed above will now be discussed in turn.

- Propagation and other losses. The UAT simulation calculates the free-space propagation loss for each transmission, using the range between transmitter and receiver at the time of transmission. There is also a receiver cable loss of 3 dB incorporated in the calculation. An optional transmit cable loss is also included in the simulation, but since the transmit powers have been defined at the antenna, the transmit cable loss has been set to zero for this study.
- Antenna gains. The antenna gain model included in the UAT simulation has been described elsewhere (Reference ***TBD***).
- Propagation delays. The propagation delay incurred by the signal in traversing the free space between transmitter and receiver has been included in the UAT simulation
- Co-channel interference. In certain geographic areas, UAT may have to co-exist with transmissions from DME/TACAN and Link 16 sources. Link 16 scenarios have been provided in cooperation with the USDOD and have been applied to all of the performance analysis shown in this document. DME/TACAN various scenarios provided by Eurocontrol have been applied to Core Europe analysis. In all cases, every attempt was made to provide conservative estimates of the co-channel interference environment.
- Co-site interference. Co-site transmissions of UAT messages, DME interrogations, Mode S interrogations and replies, whisper-shout interrogations, and ATCRBS replies are all modeled as interference in the UAT simulation. All of these are treated as “self-interference,” and it is assumed that no UAT reception may occur during any of these co-site transmissions (including a “ramp-up” and “ramp-down” period added to the beginning and end of each co-site transmission).
- Multiple interference sources. Although the UAT transmission protocol specifies that a transmission begin on one of a fixed number of message start opportunities, the propagation delay described above will cause the arrivals of messages at the victim receiver to be quasi-random. There may be a number of messages overlapping one another, and these overlaps will be for variable amounts of time. This interference is accounted for in the multi-aircraft simulation. Multiple UAT interferers are treated in the receiver performance model by combining their interference levels in a way consistent with bench test measurements. The simultaneous presence of UAT interference, co-channel interference, and self-interference is treated in a detailed fashion by the model.
- Alternating transmissions. The model simulates the alternating transmission sequence specified for A1, A2, and A3 equipage, TTBBTTBB…, where T = top and B = bottom. For A0 equipage, the model simulates transmission from a bottom antenna.
- Receiver diversity. For A2 and A3 equipage, the model simulates receiver diversity by calculating the message error rate at both the top and bottom receive antennas and calculating the joint reception probability. For A1 equipage, the model simulates the single-receiver dual-antenna configuration by switching the receive antenna

alternately between top and bottom each successive second. For A0-equipped aircraft, reception is only permitted from a bottom antenna.

- Transmit power variability. The transmit power for an aircraft is chosen from a uniform distribution given by the limits specified for the aircraft equipage.
- FIS-B data transmissions. Since the UAT system description specifies that the ground uplink transmissions occur in a separate, guarded time segment than the air-to-air transmissions, FIS-B should not interfere with the ADS-B transmissions of the aircraft. Therefore, the simulation does not model this data load.
- Receiver retriggering. The UAT simulation checks each individual ADS-B message arriving at the victim receiver for its message error rate. This procedure amounts to allowing for retriggering in the receiver.
- Receiver performance model. The receiver performance model described in Section K-2 is used in the UAT simulation.
- Message transmission sequence and content. Section 2.2 defines the types of messages, their content, and the sequence of messages transmitted for each category of aircraft equipage. This is modeled by the multi-aircraft simulation.

K.2 Receiver performance model

K.2.1 Measured Data

Measurements of the Bit Error Rate (BER) receive performance were made on two "Pre-MOPS" UAT transceivers, one with a nominal 1.2 MHz bandwidth and one with a nominal 0.8 MHz bandwidth. Simultaneous measurements were made while the same input signal was applied to both units. The input signal consisted of a Signal of Interest (SOI), from a nominal 1.5 MHz bandwidth UAT transceiver, summed with the following interference signals:

1. No external interference (internal receiver noise only). SOI level was varied to achieve various Signal-to-Noise Ratios (SNRs). Note that SNR depends on the noise bandwidth used, which will be defined later in this section.
2. White Gaussian interference. SOI level was varied to achieve various SNRs.
3. A single UAT (1.5 MHz bandwidth) interferer. The levels of both SOI and interferer were independently varied to achieve various SNRs and various Interference-to-Noise Ratios (INRs).
4. A simulated combination of multiple UAT (1.5 MHz bandwidth) interferers. An Arbitrary Waveform Generator (AWG) produced these combination signals by playing back a variety of input data files. The input data files were generated from a set of single-UAT files recorded by a digital oscilloscope. These files were adjusted in level, offset in time and summed together to create the multi-UAT scenarios of interest, specifically:
5. Two UATs, both at the same level, and at various INRs.
6. Two UATs at high INR and at various relative levels.
7. Three, five and ten UATs, all at the same level and at high INR.
8. (As a check on the fidelity of the simulation, a single UAT at high INR was also simulated and measured and the BER was compared with the corresponding BER measured using an actual UAT at high INR.)

9. A DME interferer emitting pulse pairs with 12-usec separation. DME signals at two frequencies were used, at the SOI center frequency and one MHz above. The level of the SOI was varied to achieve a wide range of Signal-to-Interference Ratios (SIRs). The variation of BER with time during and shortly after the DME pulse pair was measured.
10. A Link 16 interferer, at various frequencies, at the SOI center frequency, three MHz higher, 6 MHz higher and so on up to 21 MHz higher. The level of the SOI was varied to achieve a wide range of Signal-to-Interference Ratios (SIRs). The variation of BER with time during and shortly after the Link 16 pulse pair was measured.

K.2.2 Receiver Model Assumptions

Based on the above BER measurements, a computer program (the "UAT BER Model") was designed to estimate Pre-MOPS UAT BER performance under arbitrary combinations of UAT, DME and Link 16 interference. The UAT BER Model is incorporated within the Multi-Aircraft UAT Simulation (MAUS), which uses the BER estimates to evaluate the reception success of UAT messages.

The following simplifying assumptions were made in the UAT BER Model:

1. The variation of BER with Signal-to-Interference-Plus-Noise Ratio (SINR) for any given interference scenario is specified by just three parameters, B0, B1 and B2. In terms of the variable $\log_{10}(-\log_{10}(2^*BER))$, called "llBER" in the following, every BER(SINR) relationship is specified by a 3-segment piecewise linear llBER Vs. SINR curve (for SINR specified in dB), as shown in Figure K-1. The parameters B1 and B2 are the SINR values at the llBER values of -0.5 for the first segment and +0.5 for the 3rd segment. The 1st and 3rd segments intersect at SINR = B0. The second segment simply rounds off the knee at B0 by connecting the points at llBER = -0.1 and +0.1. The corresponding BER Vs. SINR curve is shown in Figure K-2.

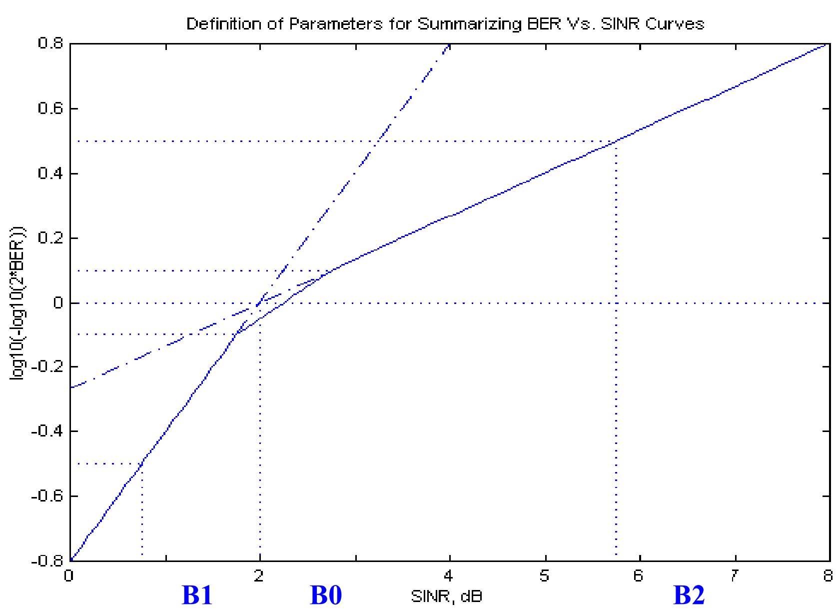


Figure K-1: Assumed Piecewise Linear llBER Vs. SINR Curve

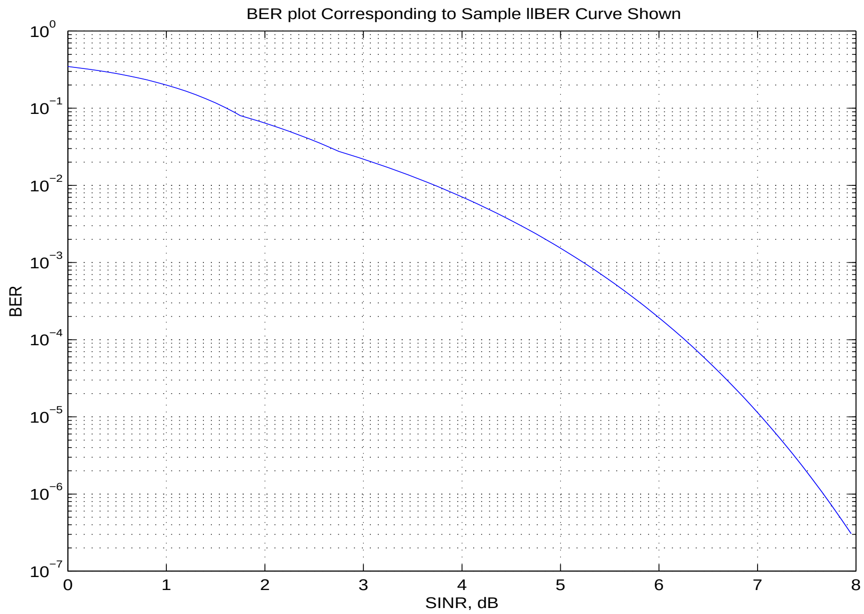


Figure K-2: BER Vs. SINR Curve Corresponding to Figure K-1

2. For multiple UAT interferers, the BER is determined only by the SINR, the INR, and the difference in level, dI, between the 2 strongest UAT interferers. If INR<<0 (INR specified in dB), BER is unaffected by dI. If there are more than two simultaneous UAT interferers, the 3rd strongest and all weaker ones have the same impact as noise sources of the same power levels (measured in a noise bandwidth yet to be specified), so their powers are understood to be included in the noise term for computing INR. The interference term in INR is the power sum of the two strongest interferers only.

3. For combined Gaussian noise and multiple UAT interference, the variation in each of the parameters B0, B1 and B2 with INR for any given value of dI follows a 4-parameter sigmoid curve of the form:

$$B = a + b \cdot \frac{INR - d}{\sqrt{c^2 + (INR - d)^2}} \ ,$$

   where the parameters a, b, c and d are given by:

   - a = {B(INR>>0) + B(INR<<0)}/2,
   - b = {B(INR>>0) - B(INR<<0)}/2,
   - d = INR at which B = a, and
   - c = b divided by the slope of the B(INR) curve at INR = d.

4. For combined Gaussian noise and multiple UAT interference, the variation in each of the parameters B0, B1 and B2 with dI follows a 3-parameter sigmoid curve of the form:

$$B = a + b \cdot \frac{dI}{\sqrt{c^2 + dI^2}} \ ,$$

   where the parameters a, b, and c are given by:

   - a = B(dI=0),
   - b = {B(dI>>0) - B(dI=0)}, and
   - c = b divided by the slope of the B(INR) curve at dI = 0.

5. Assumptions (2, 3 and 4) together mean that any of the three B parameters for any combination of Gaussian noise and multiple UAT interference may be specified by eight parameters (a0,b0,c0,d0 to describe B(INR) when dI>>0; b1,c1,d1 to describe B(INR) when dI=0; and c2 to describe B(dI) when INR>>0. The requirement of continuity of B(INR,dI) determines the remaining parameters:

   - a1 = (a0 - b0) + b1,
   - a2 = B(INR) for dI = 0, and
   - b2 = B(INR) for dI>>0 - a2.

6. The BER impact of combining DME with other UAT interference and with receiver noise is the same as if the DME interference on any bit were replaced by an additional UAT interferer with a level such that it alone would produce the same BER as the DME interference alone.

7. The BER impact of combining Link 16 with other UAT interference and with receiver noise is the same as if the Link 16 interference on any bit were replaced by an additional Gaussian noise interferer with a level such that it alone would produce the same BER as the Link 16 interference alone.

With the above assumptions, BER is determined for every combination of Gaussian noise, multiple UAT, DME and Link 16 interference, by SINR, INR and dI, as defined above, together with 24 parameters. These parameters are then determined for each of the two Pre-MOPS UAT receive bandwidths as the values that best fit the measured Gaussian noise plus UAT interference data.

One additional parameter, the appropriate noise bandwidth must also be specified. This is conveniently represented as dN, the increase in effective noise power over that computed for a 1 MHz bandwidth. Initially, dN was chosen to equalize the SNR required for a given BER when interference was pure Gaussian noise with the SIR required when interference was ten equal-power UAT interferers. Subsequently, it was found that a better overall fit could be obtained with dN about 2 dB higher (bandwidth 60% larger). The dN values used are +1.5 dB for the 1.2 MHz bandwidth UAT and 0 dB for the 0.8 MHz bandwidth UAT.

K.2.3 Receiver Model Accuracy

Figures K-3 through K-10 show the measured and modeled BER Vs. SINR curves for five subsets of the measured data and for both UAT receive bandwidths. Figures K-11 and K-12 show the BER modeling error for all the Gaussian noise plus UAT interference data so as to indicate the equivalent power error in dB. The BER-to-power curve used for Figures K-13 and K-14 is the curve appropriate for pure Gaussian noise interference. With this measure, it can be seen that most of the data is modeled to + or – 1.5 dB accuracy.

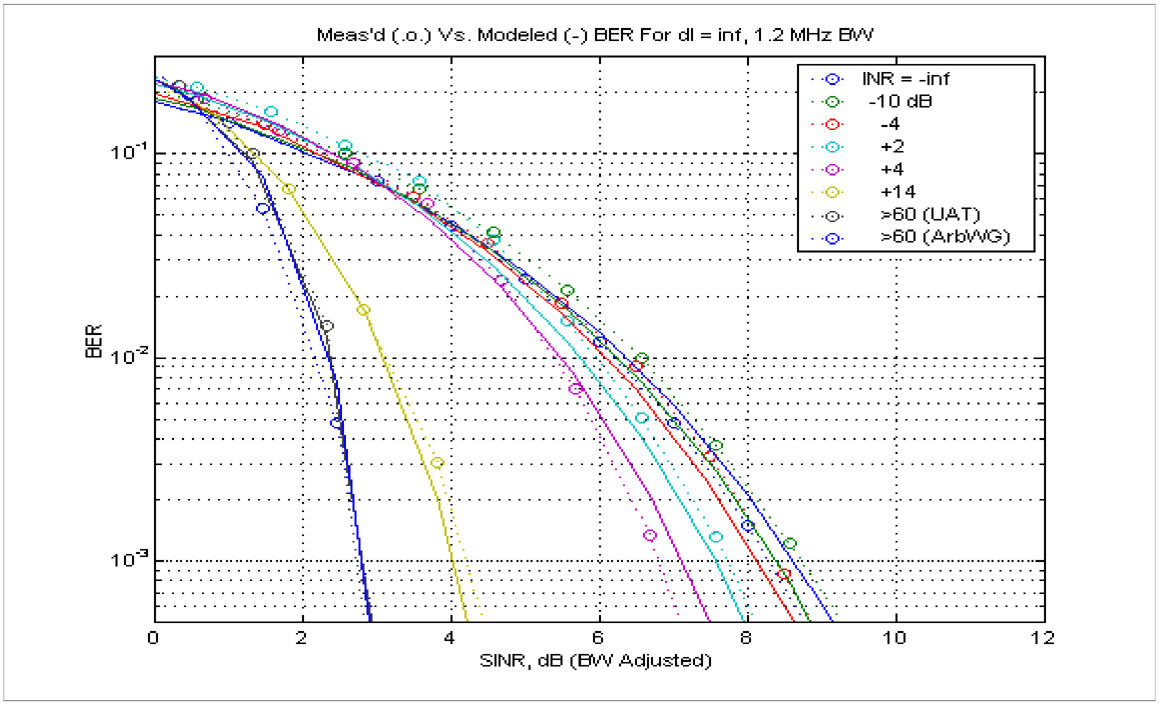


Figure K-3: **Gaussian Noise + Single UAT, 1.2 MHz Receiver**

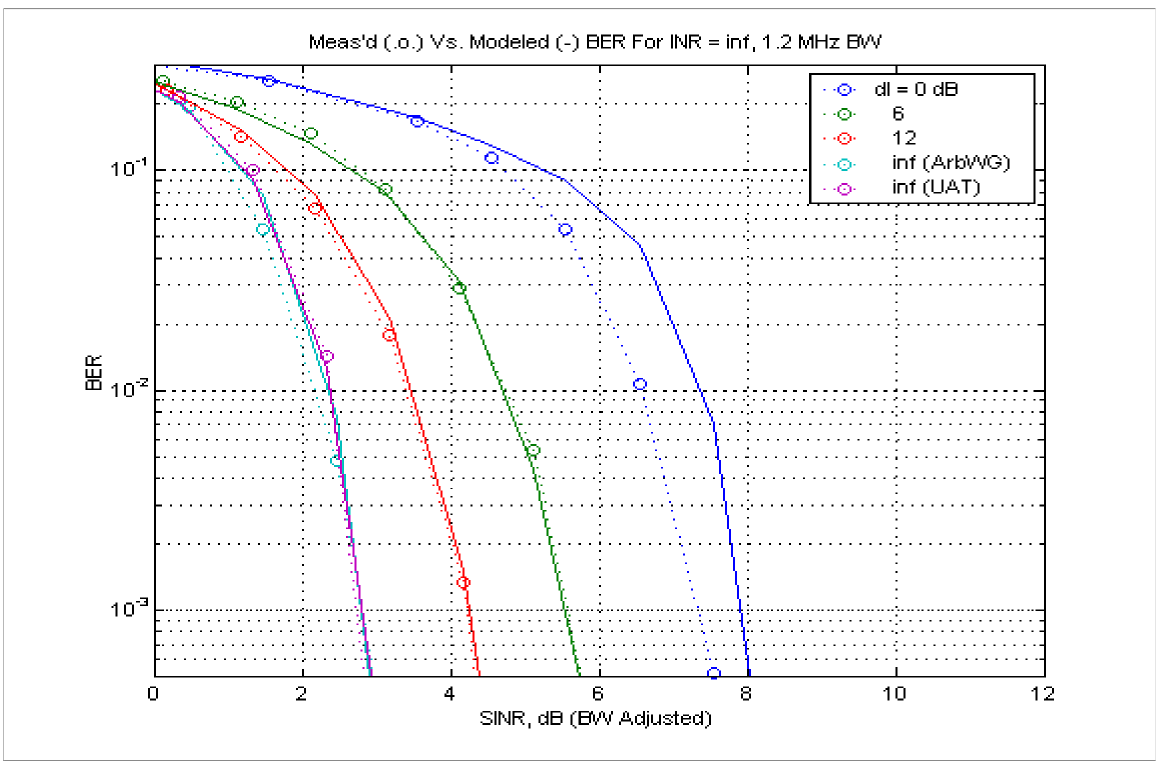
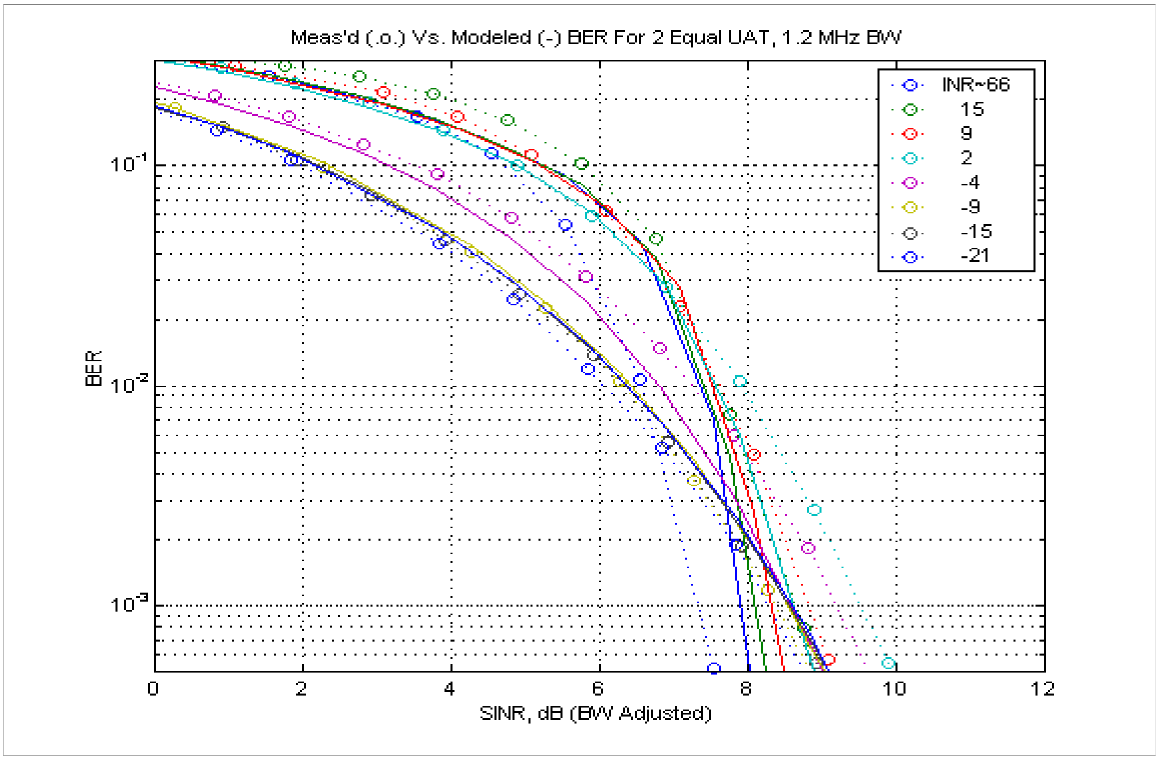
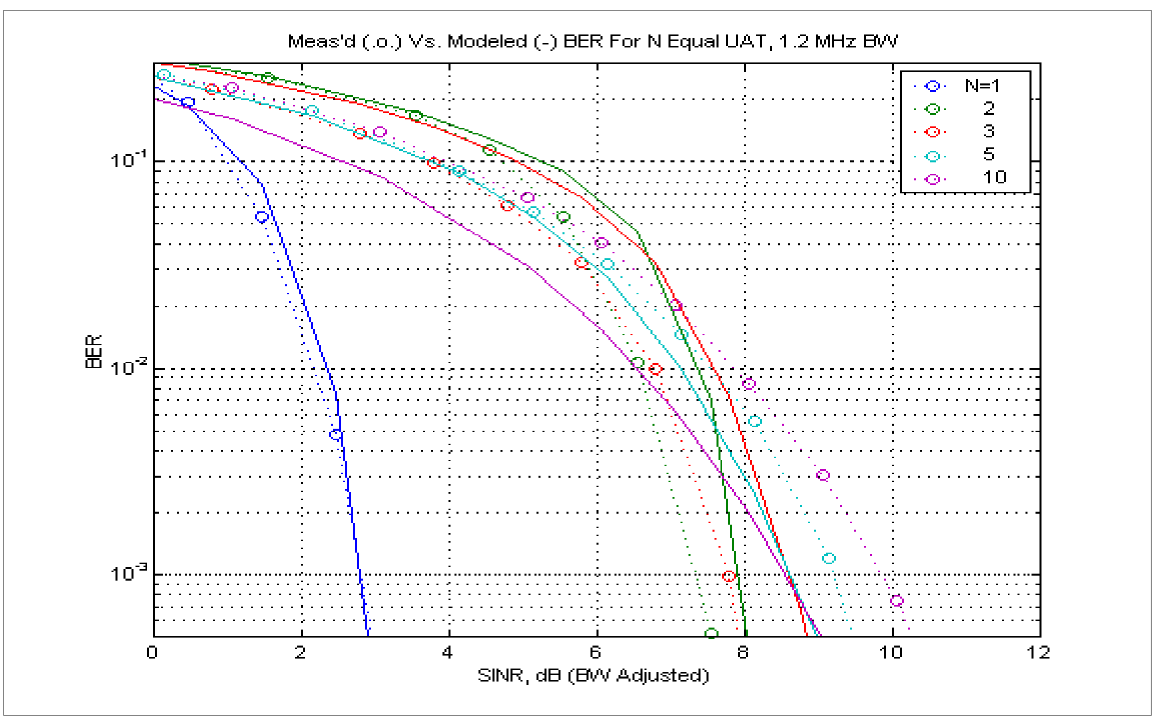


Figure K-4: **Two Unequal UATs, INR >> 0 dB, 1.2 MHz Receiver**



<u>Figure K-5:</u> Gaussian Noise + Two Equal UATs, 1.2 MHz Receiver



<u>Figure K-6:</u> N Equal UATs, INR >> 0, 1.2 MHz Receiver

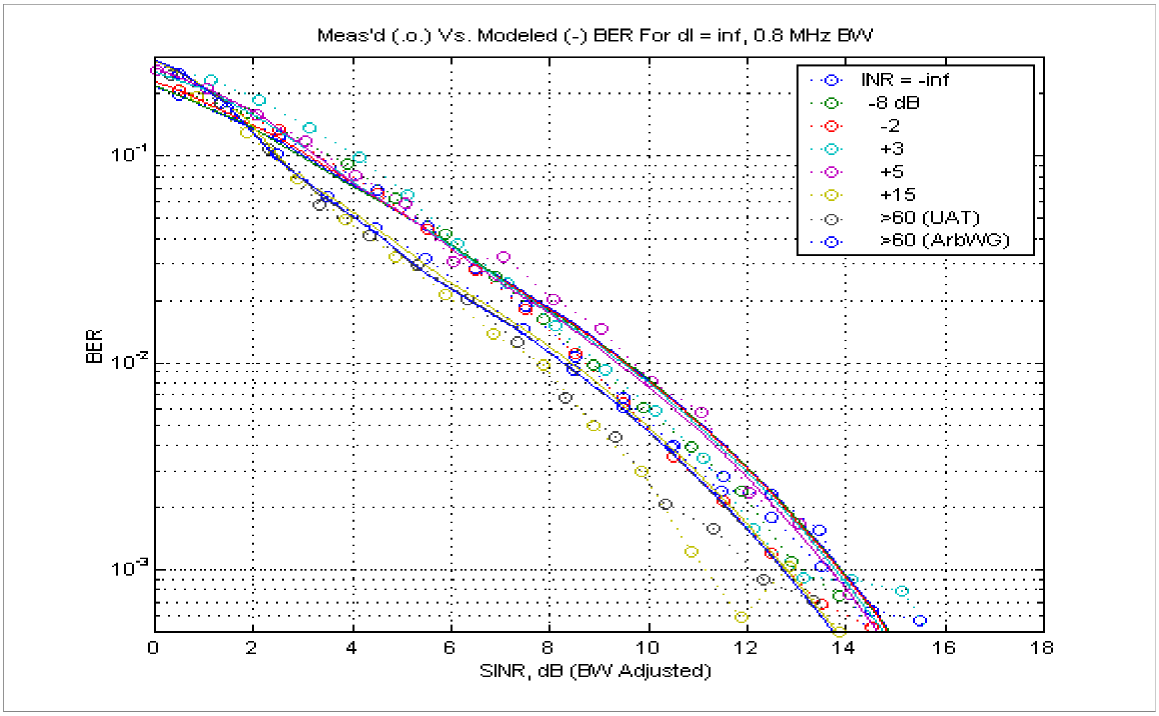


Figure K-7: **Gaussian Noise + Single UAT, 0.8 MHz Receiver**

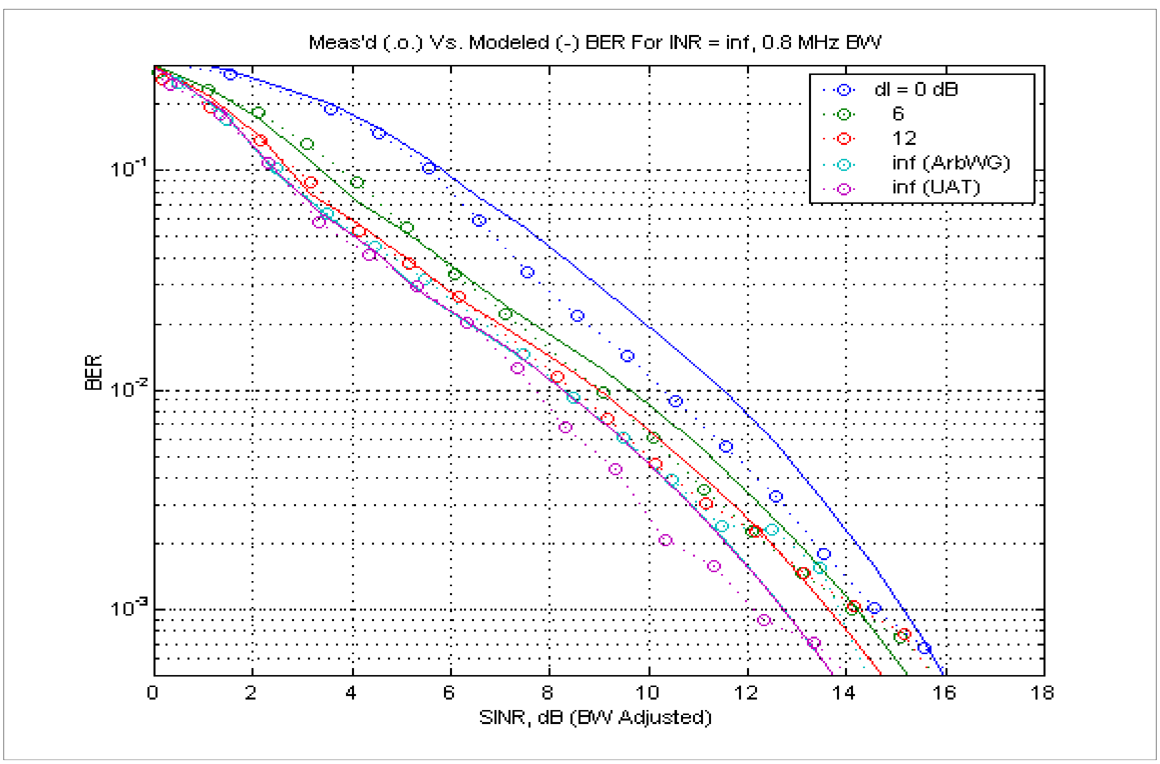


Figure K-8: **Two Unequal UATs, INR >> 0 dB, 0.8 MHz**

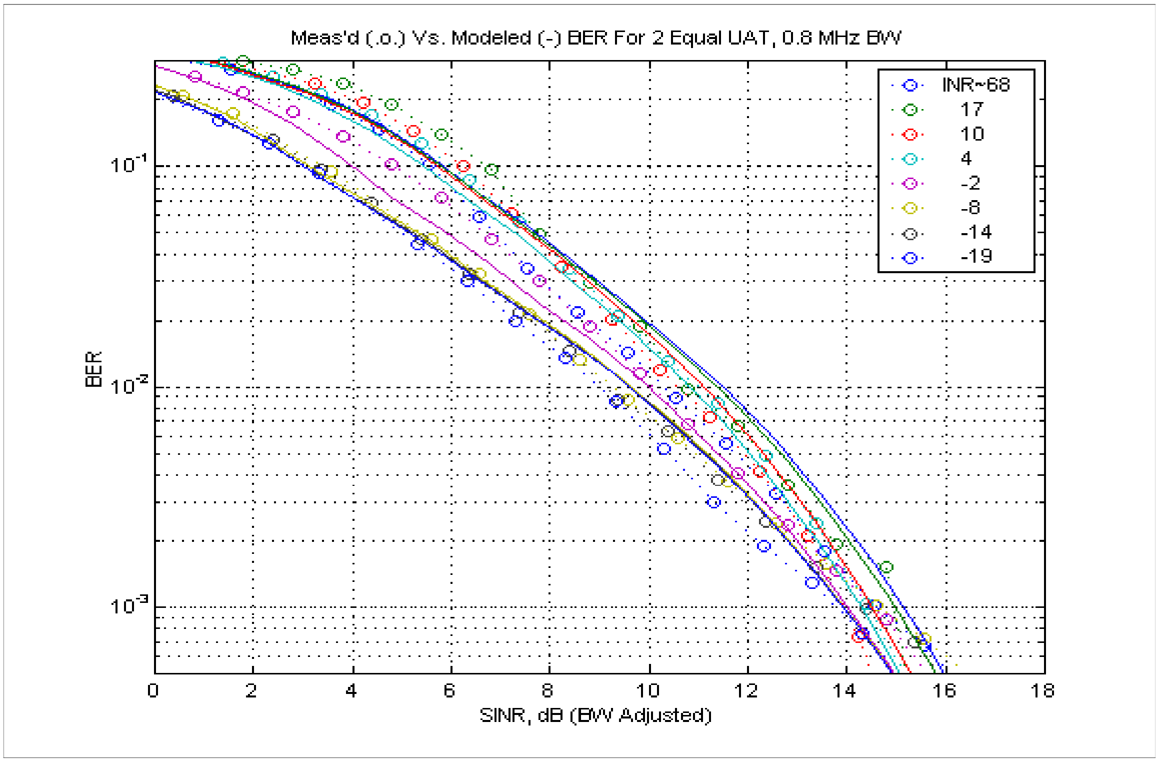


Figure K-9: **Gaussian Noise + Two Equal UATs, 0.8 MHz Receiver**

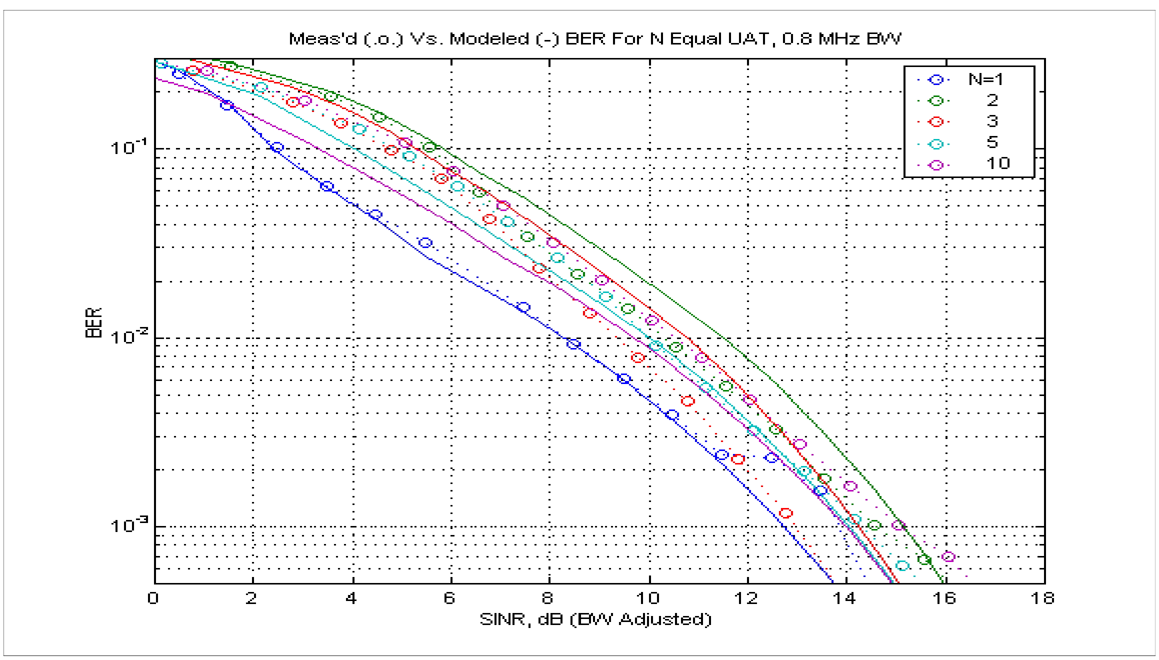


Figure K-10: **N Equal UATs, INR >> 0, 0.8 MHz Receiver**

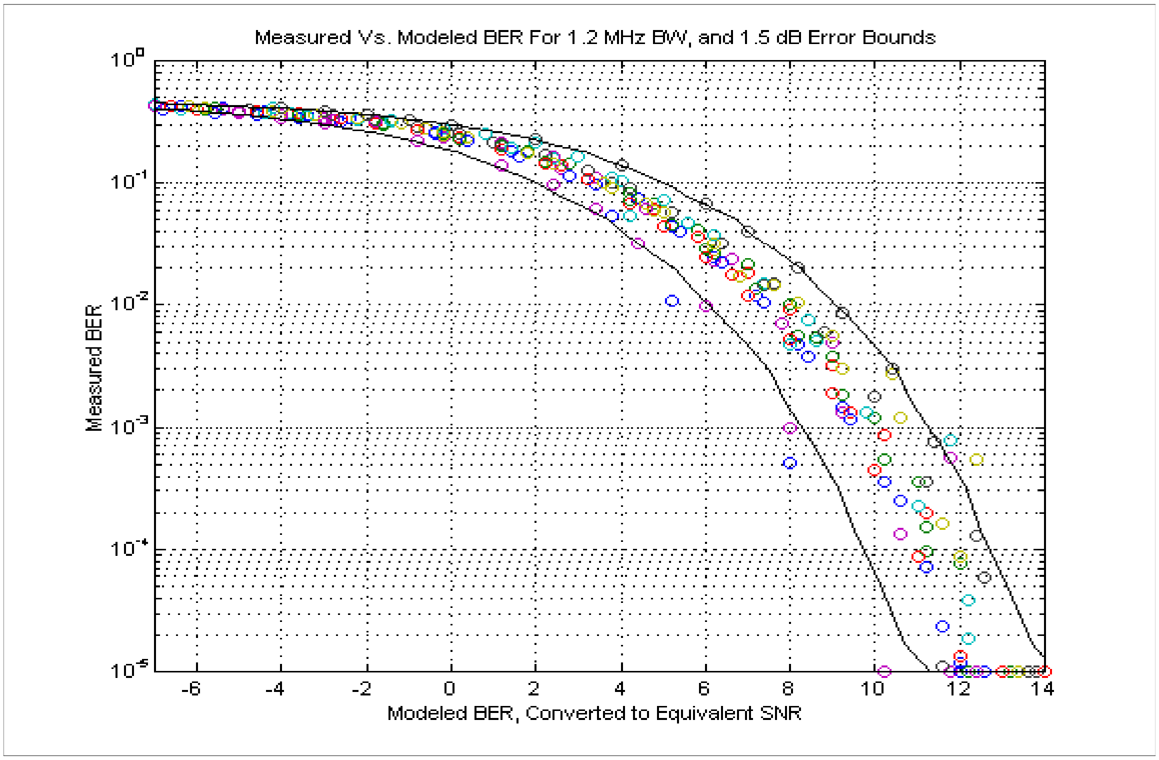


Figure K-11: **Model Errors for All Data, 1.2 MHz Receiver**

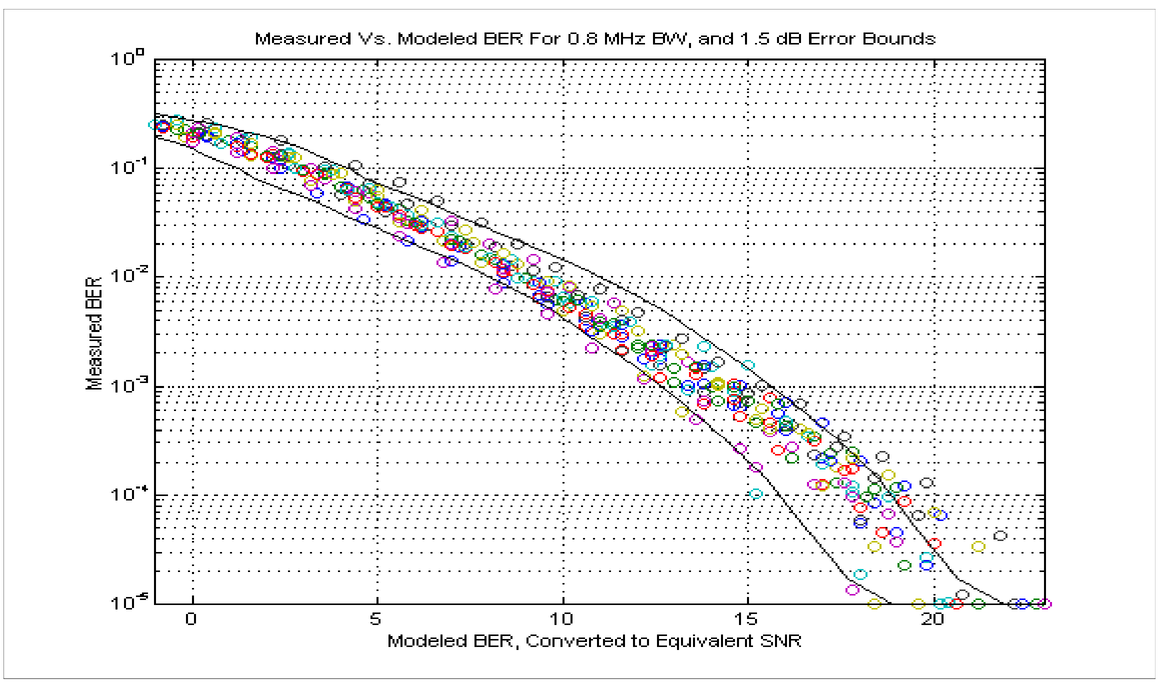


Figure K-12: **Model Errors for All Data, 0.8 MHz Receiver**

K.3 Multi-aircraft simulation (MAUS) results

K.3.1 Los Angeles Basin 2020 (LA2020)

This scenario is based on the LA Basin 1999 maximum estimate. It is assumed that air traffic in this area would increase by a few percent each year until 2020, when it would be 50 % higher than in 1999. The distribution of aircraft in the scenario is based on approximations of measured altitude and range density distributions.

The following assumptions are made for the airborne and ground aircraft and ground vehicles for the LA Basin 2020 scenario:

- The density of airborne aircraft is taken to be:
  - Constant in range from the center of the area out to 225 nautical miles (5.25 aircraft/NM), (i.e., the inner circle of radius one NM would contain approximately five aircraft, as would the ring from 224 to 225 NM) and
  - Constant in area from 225 NM to 400 NM (.00375 aircraft/NM^2).
- There are assumed to be a fixed number of aircraft on the ground (within a circle of radius 5 NM at each airport), divided among LAX, San Diego, Long Beach, and five other small airports, totaling 225 aircraft. Half of the aircraft at each airport were assumed to be moving at 15 knots, while the other half were stationary. In addition, a total of 300 ground vehicles are distributed at these airports as well.
- The altitude distribution of the airborne aircraft is assumed to be exponential, with a mean altitude of 5500 feet. This distribution is assumed to apply over the entire area.
- The airborne aircraft are assumed to have the following average velocities, determined by their altitude. The aircraft velocities for aircraft below 25000 feet are uniformly distributed over a band of average velocity +/- 30 percent.
  - 0-3000 feet altitude 130 knots
  - 3000-10000 ft 200 knots
  - 10000-25000 ft 300 knots
  - 25000-up 450 knots
- The aircraft are all assumed to be moving in random directions.
- ADS-B MASPS equipage class A0 aircraft are restricted to fly below 18000 feet. All other aircraft are assumed to be capable of flying at any altitude. The aircraft in the LA 2020 scenario are assumed to be in the following proportions:
  - A3 30%
  - A2 10%
  - A1 40%
  - A0 20%

The scenario for the 2020 high density LA Basin case contains a total of 2694 aircraft: 1180 within the core area of 225 NM, 1289 between 225-400 NM, and 225 on the ground. This represents a scaling of the estimated maximum 1999 LA Basin levels upward by 50 percent. Of these aircraft, 471 lie within 60 NM of the center. (This includes aircraft on the ground.) Around ten percent of the total number of aircraft are above 10000 ft in altitude, and more than half of the aircraft are located in the outer (non-core) area of the scenario.

An attempt was made to at least partially account for the expected lower aircraft density over the ocean. In the third quadrant (between 180 degrees and 270 degrees), for distances greater than 100 NM from the center of the scenario, the density of aircraft is reduced to 25 % of the nominal value used. The other 75 % of aircraft which would have been placed in this area are distributed uniformly among the other three quadrants at the same range from the center. This results in relative densities of 1:5 between the third quadrant and the others.

K.3.2 Results and Analysis

The ADS-B MASPS requirements for ADS-B air-to-air surveillance range and report update interval are used to assess how the candidate links perform in relation to the free flight operational enhancements identified by the SF21 Steering Committee. These requirements specify the minimum range for acquisition of the state vector and the mode-status and TC and TS reports where applicable, as well as the maximum update period. (See Reference ???.)

Eurocontrol criteria augment those of the ADS-B MASPS with specific air/ground performance characteristics. These air/ground criteria specify ranges, use of intent information (TC and TS reports), and update times. Additionally, Eurocontrol criteria extend existing ADS-B MASPS air-to-air requirements for long-range deconfliction.

Results are presented as a series of plots of 95% update times as a function of range for state vector updates and intent updates, where applicable. The 95% time means that at the range specified, 95% of aircraft will achieve a 95% update rate at least equal to that shown. The ADS-B MASPS requirements are also included on the plots for reference. Since the transmit power and receiver configuration are defined for each aircraft equipage class, performance is shown separately for each combination of transmit-receive pair types. In addition, performance of different transmit-receive pairs is shown at several different altitudes, where appropriate. Results are shown in Figure K-13 through Figure K-38 and conclusions are presented below. The ADS-B MASPS requirements for state vector, TSR, and TCR+0 updates are shown as black lines on the plots. Although results for TCR+1 transmissions are shown, there are currently no requirements that have been set for TCR+1 reception. The ADS-B MASPS specify that the maximum ranges for air-air update rates required for A0 to 10 NM, A1 to 20 NM, A2 to 40 NM, and A3 to 90 NM (120 NM desired), while the Eurocontrol criteria continue to 150 NM for A3. Performance in compliance with MASPS requirements is indicated by results that are below the black line.

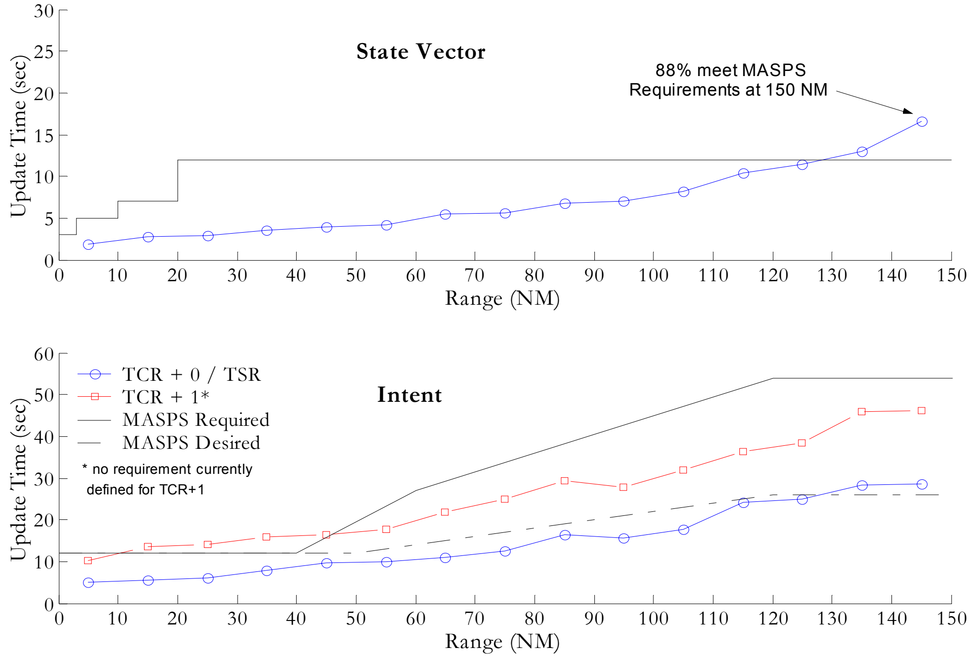


Figure K-13: **A3 Receiver at High Altitude Receiving A3 Transmitters**

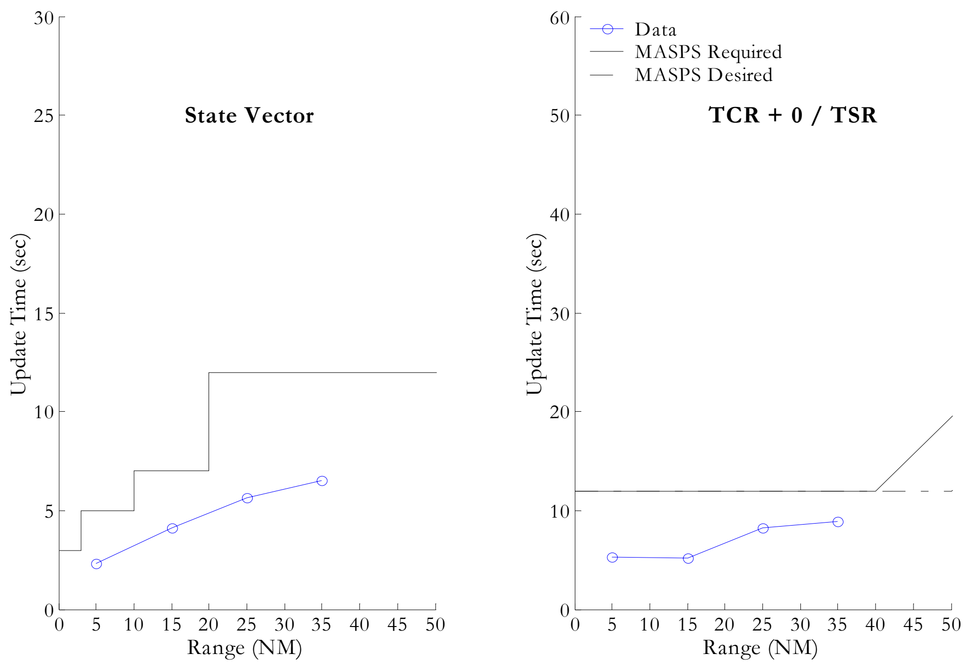


Figure K-14: **A3 Receiver at High Altitude Receiving A2 Transmitters**

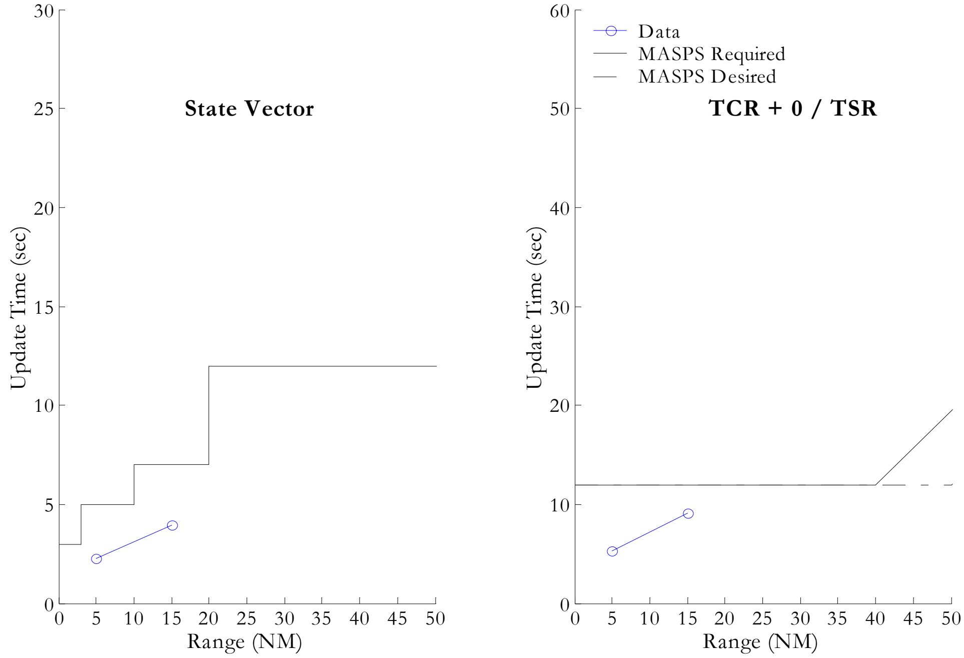


Figure K-15: A3 Receiver at High Altitude Receiving A1H Transmitters

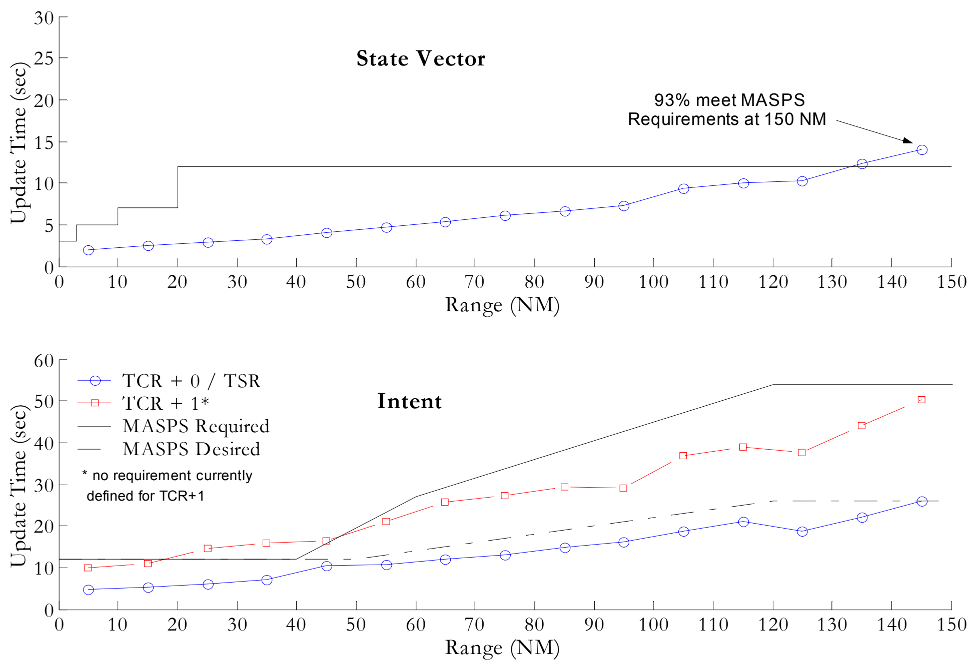


Figure K-16: A3 Receiver at FL 150 Receiving A3 Transmitters

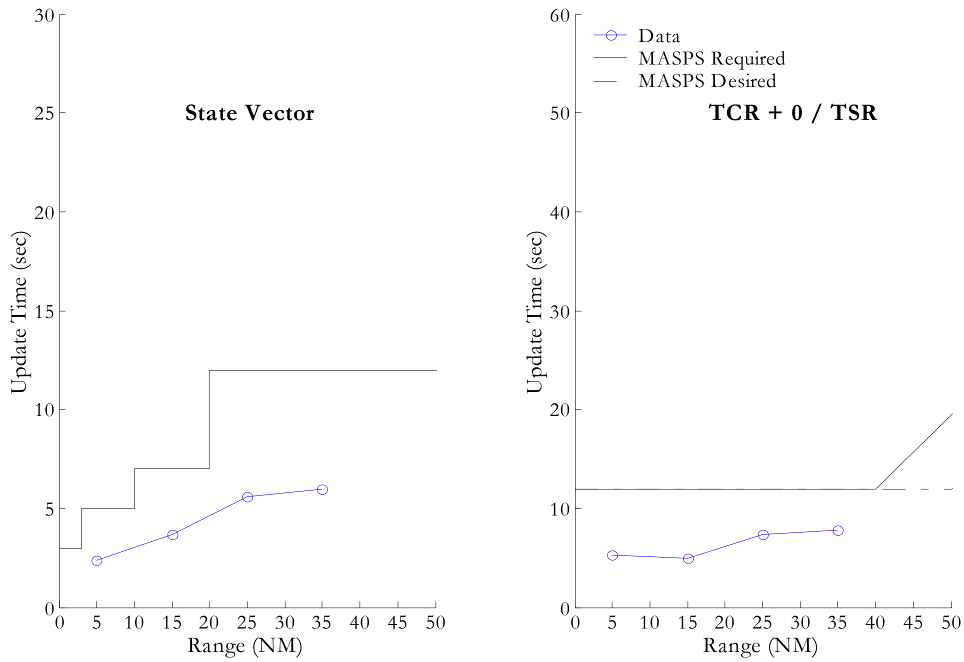


Figure K-17: **A3 Receiver at High Altitude Receiving A2 Transmitters**

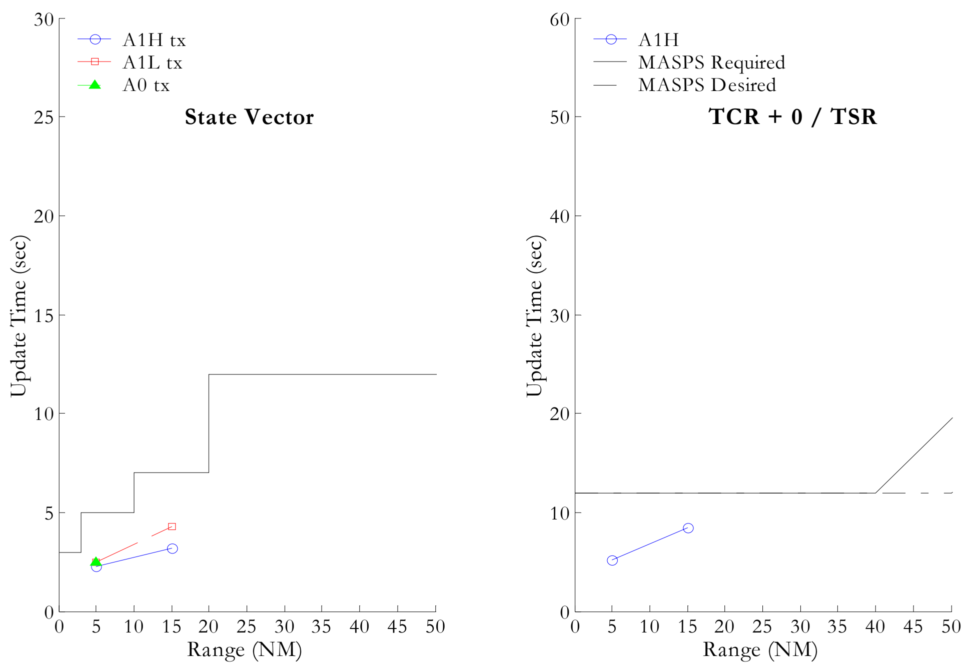


Figure K-18: **A3 Receiver at FL 150 Receiving A1 and A0 Transmitters**

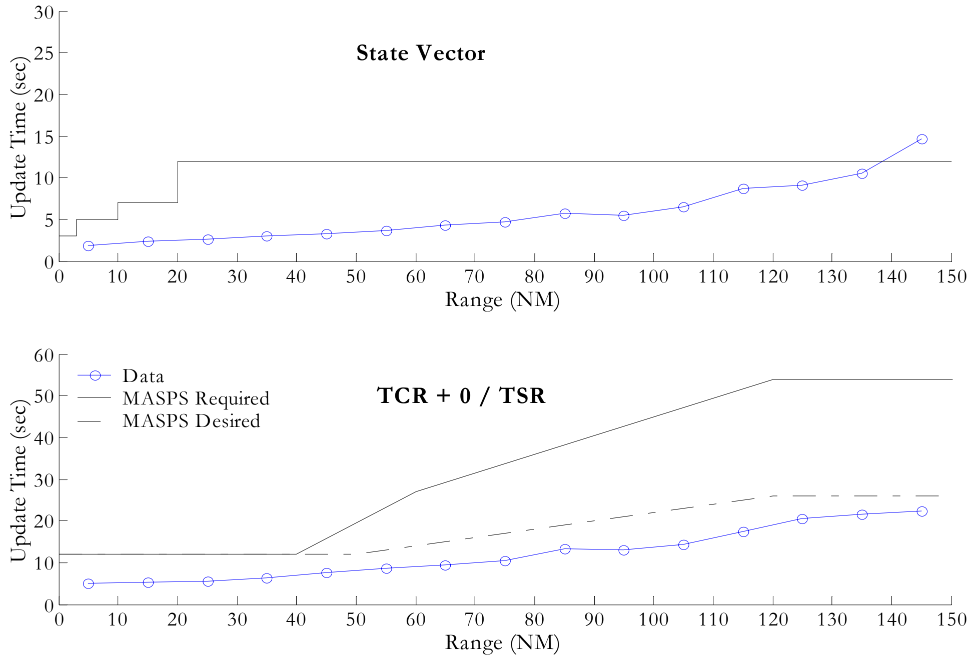


Figure K-19: A2 Receiver at High Altitude Receiving A3 Transmitters

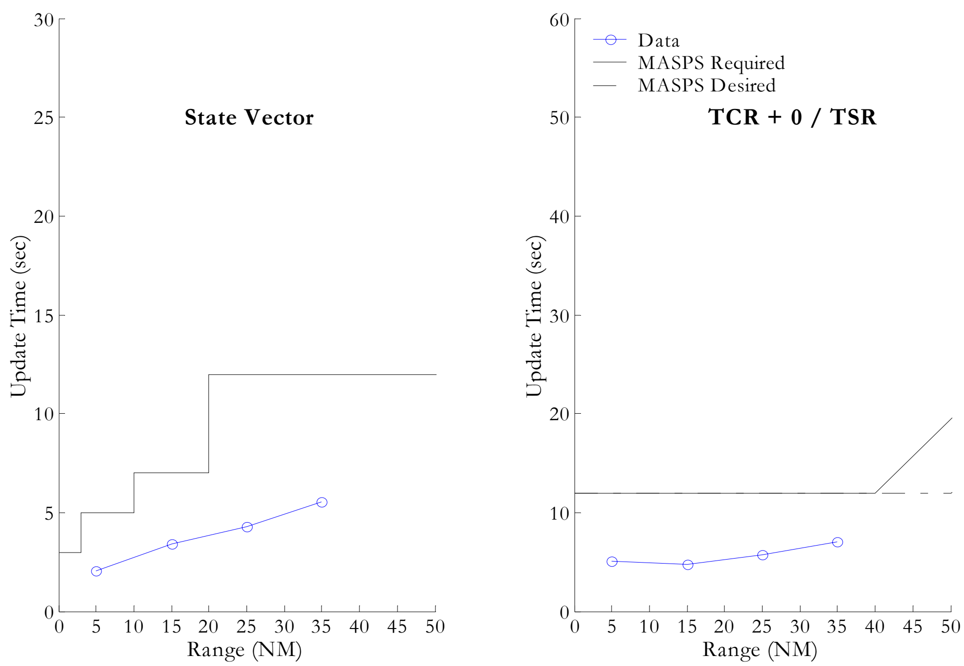


Figure K-20: A2 Receiver at High Altitude Receiving A2 Transmitters

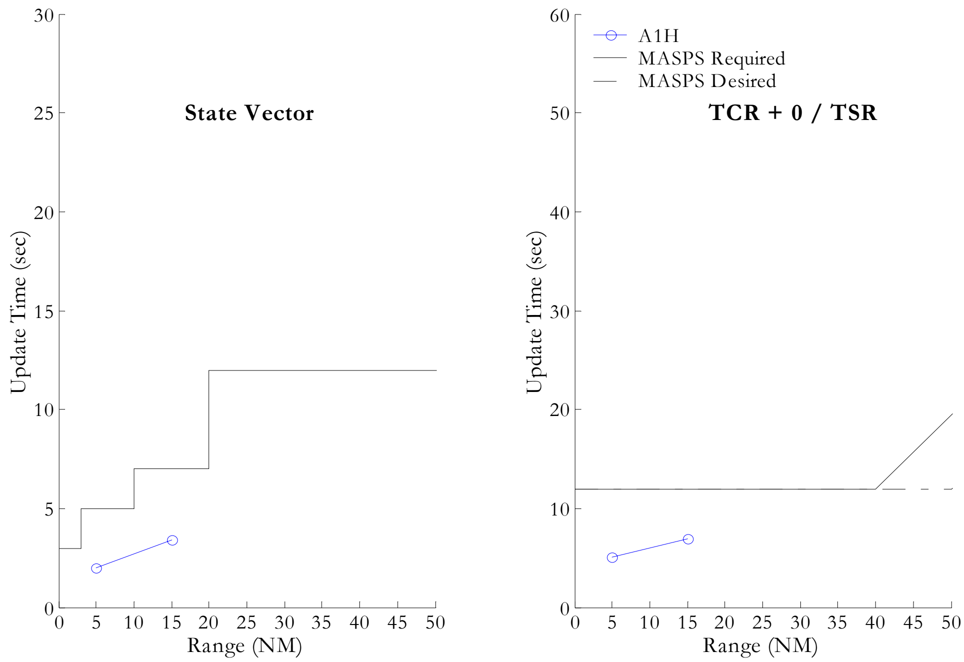


Figure K-21: A2 Receiver at High Altitude Receiving A1H Transmitters

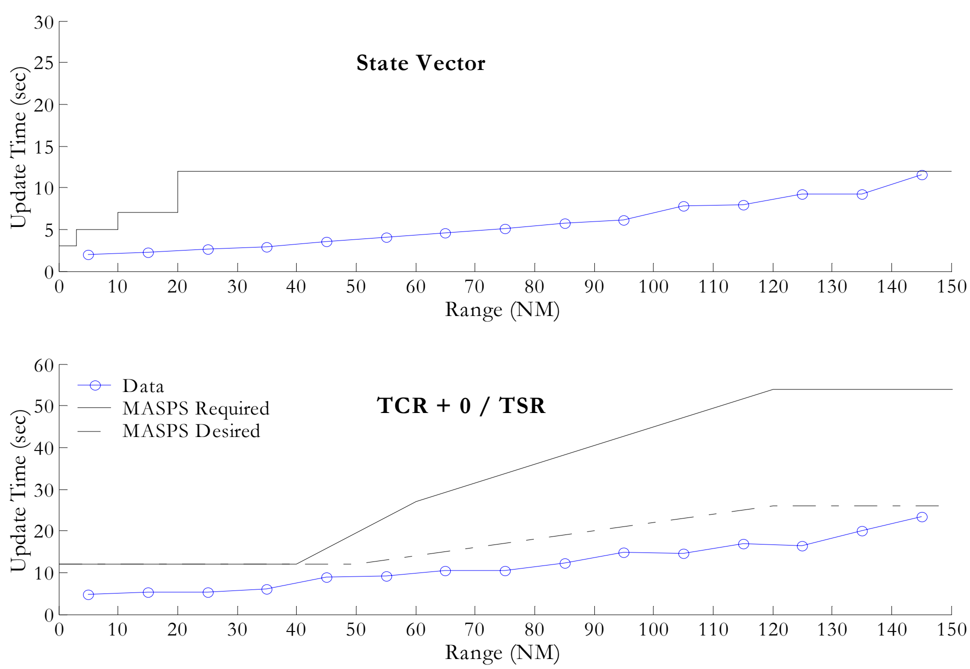
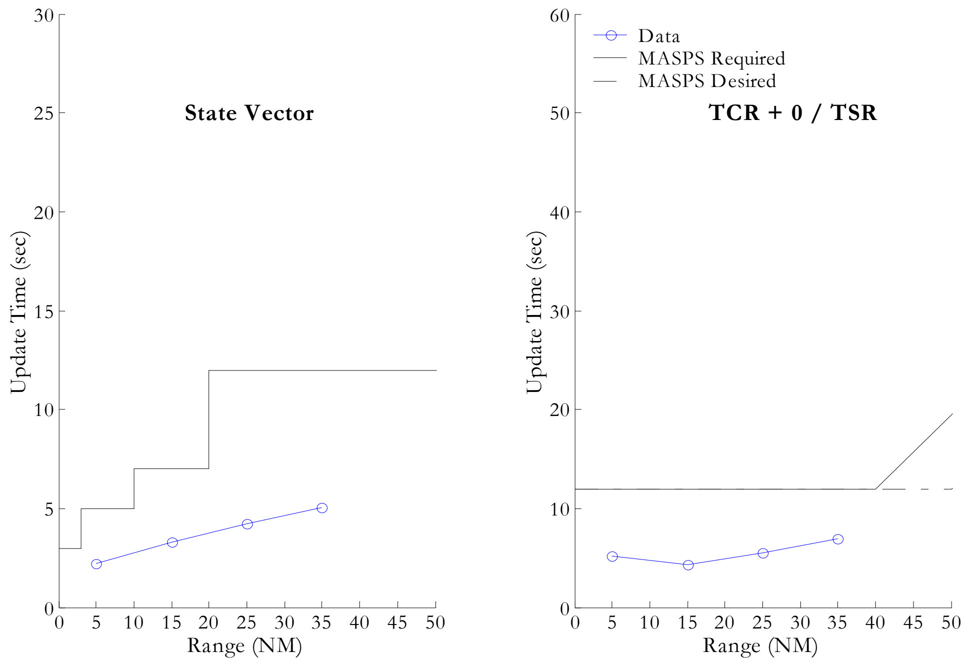
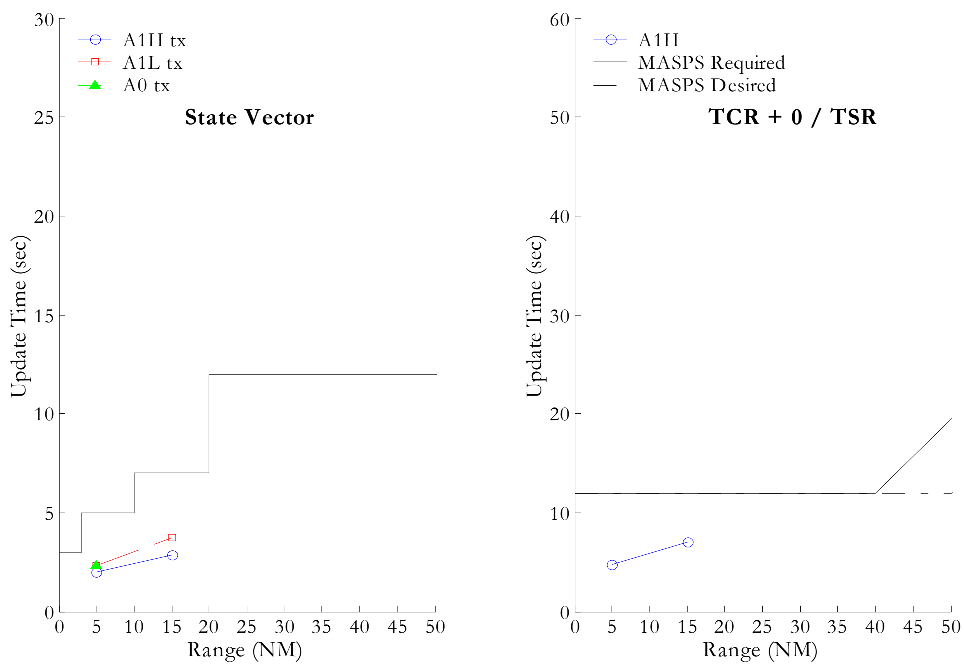


Figure K-22: A2 Receiver at FL 150 Receiving A3 Transmitters



<u>Figure K-23:</u> A2 Receiver at FL 150 Receiving A2 Transmitters



<u>Figure K-24:</u> A2 Receiver at FL 150 Receiving A1 and A0 Transmitters

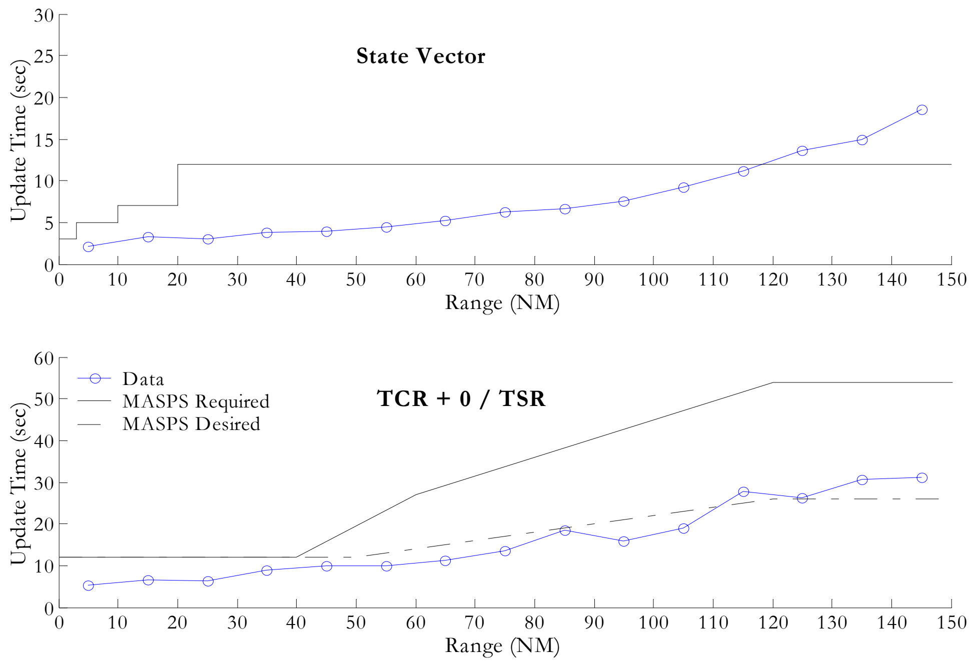


Figure K-25: **A1H Receiver at High Altitude Receiving A3 Transmitters**

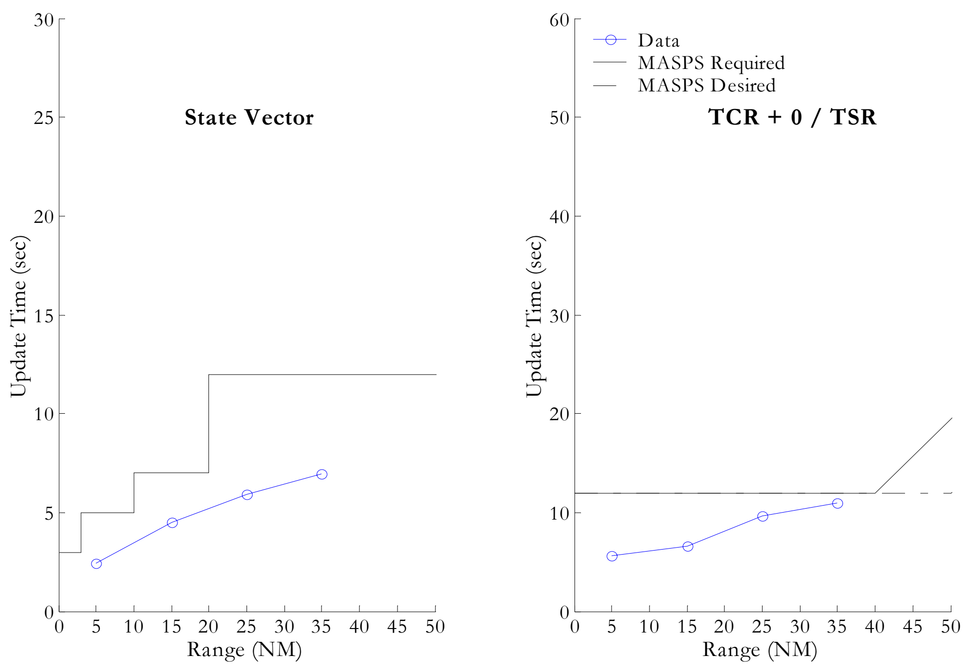


Figure K-26: **A1H Receiver at High Altitude Receiving A2 Transmitters**

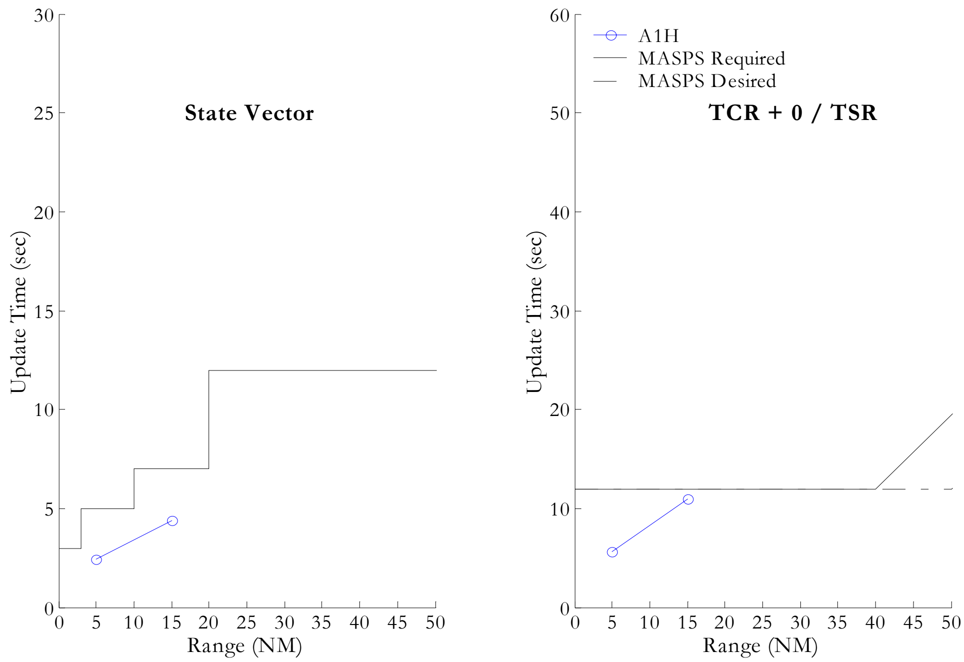


Figure K-27: A1H Receiver at High Altitude Receiving A1H Transmitters

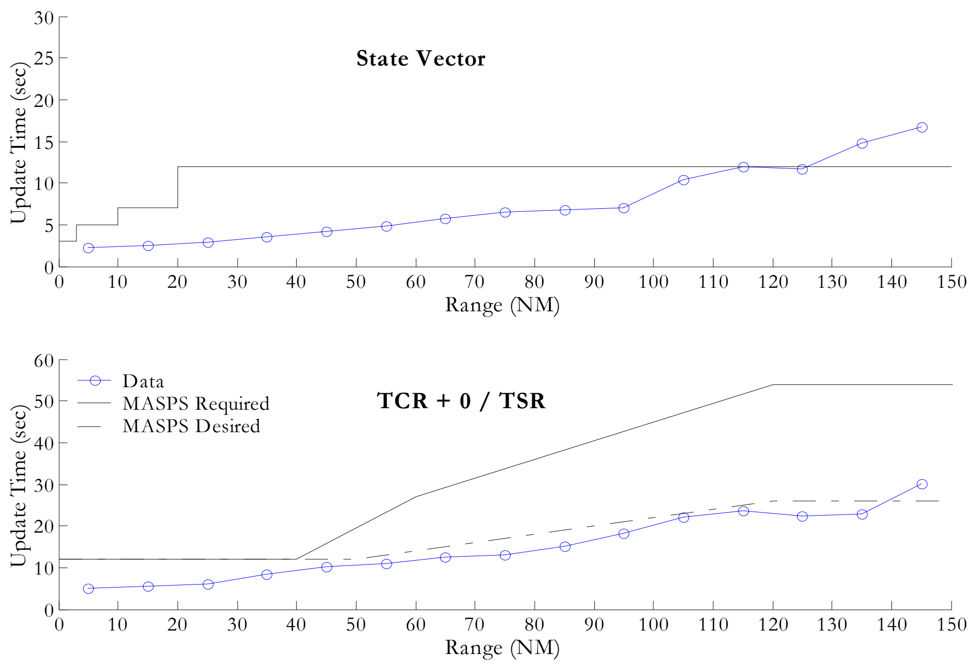


Figure K-28: A1 Receiver at FL 150 Receiving A3 Transmitters

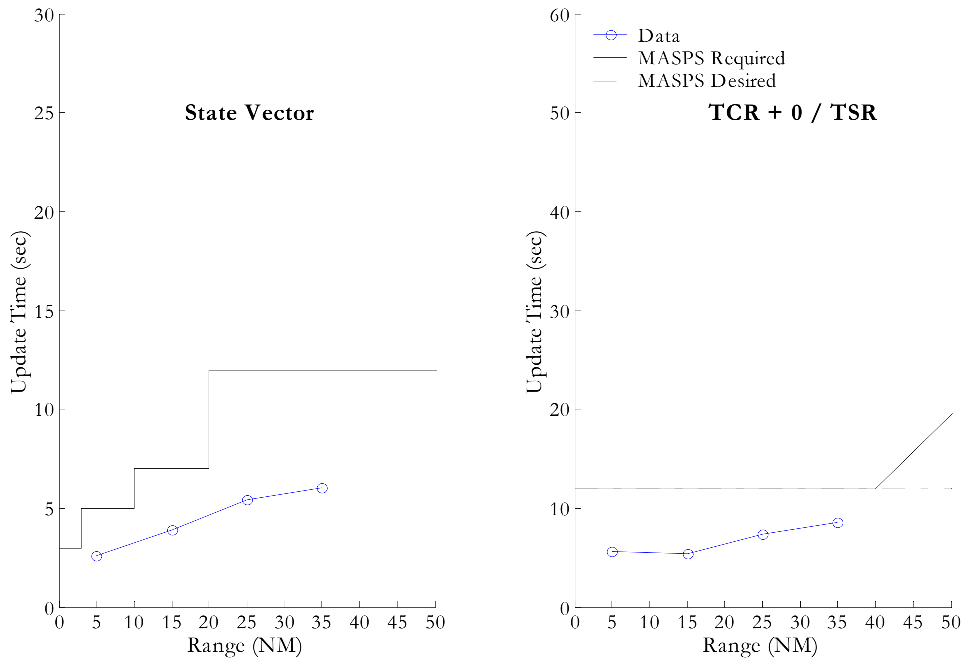


Figure K-29: A1 Receiver at FL 150 Receiving A2 Transmitters

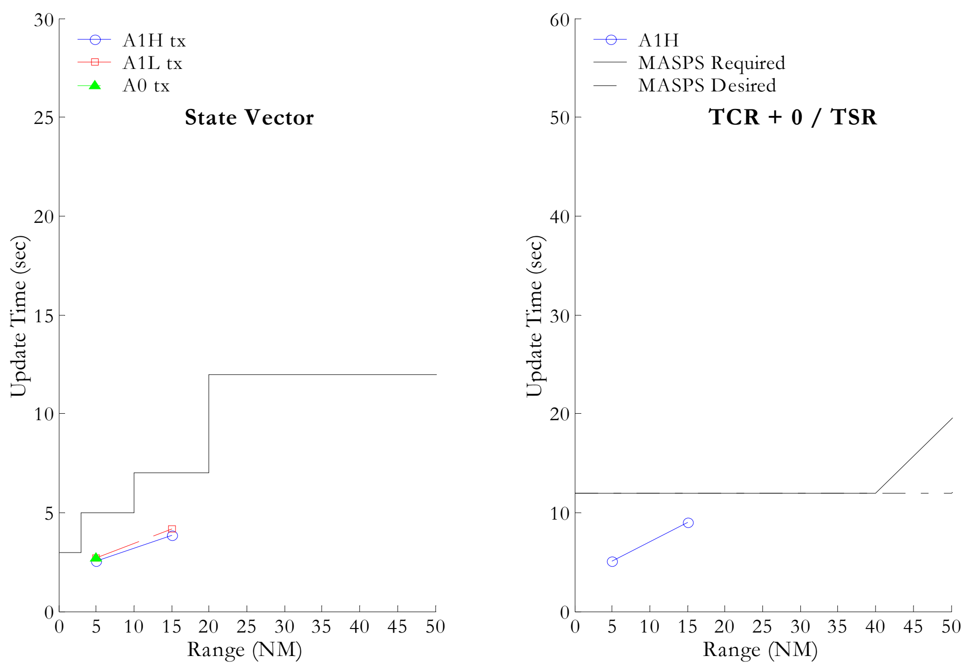


Figure K-30: A1 Receiver at FL 150 Receiving A1 and A0 Transmitters

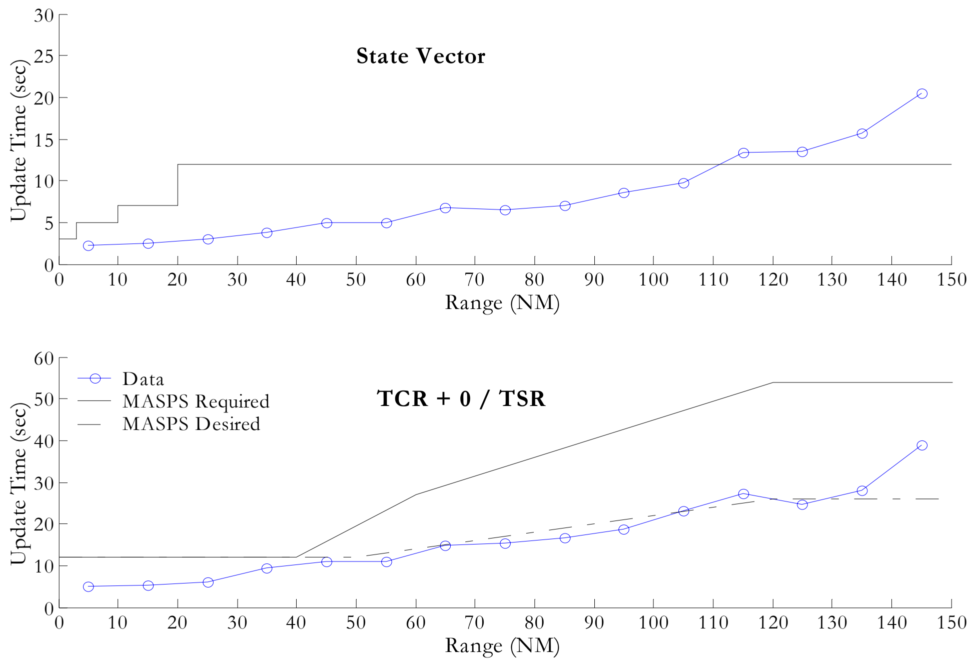


Figure K-31: **A0 Receiver at FL 150 Receiving A3 Transmitters**

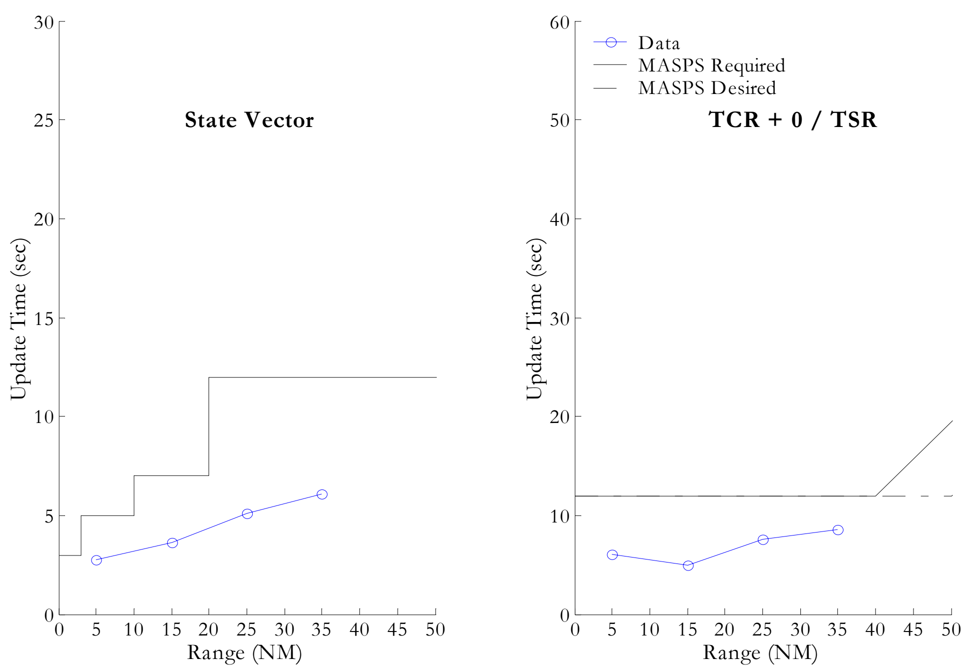


Figure K-32: **A0 Receiver at FL 150 Receiving A2 Transmitters**

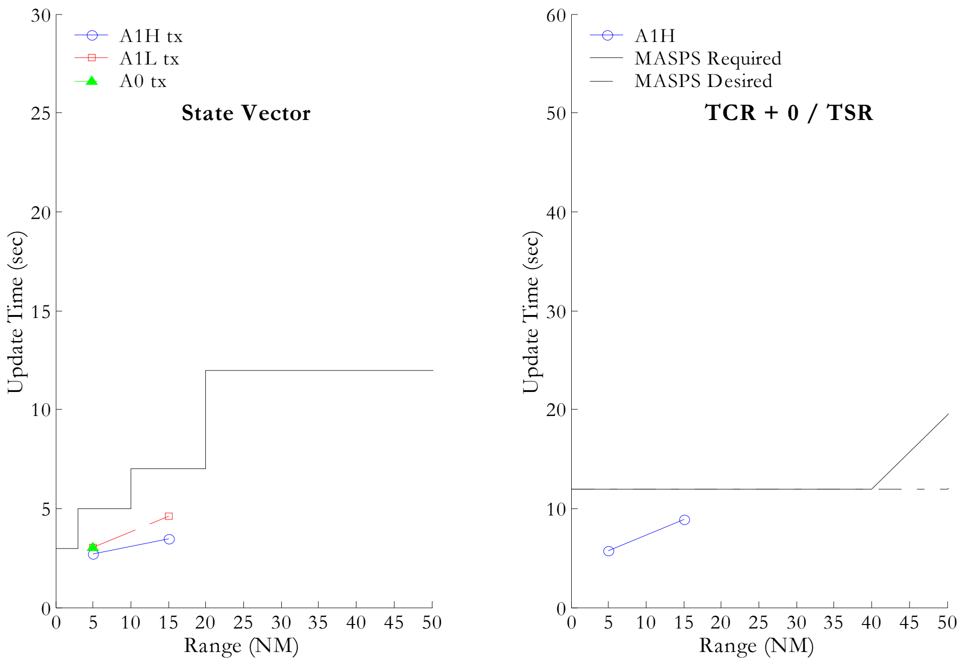


Figure K-33: **A0 Receiver at FL 150 Receiving A1 and A0 Transmitters**

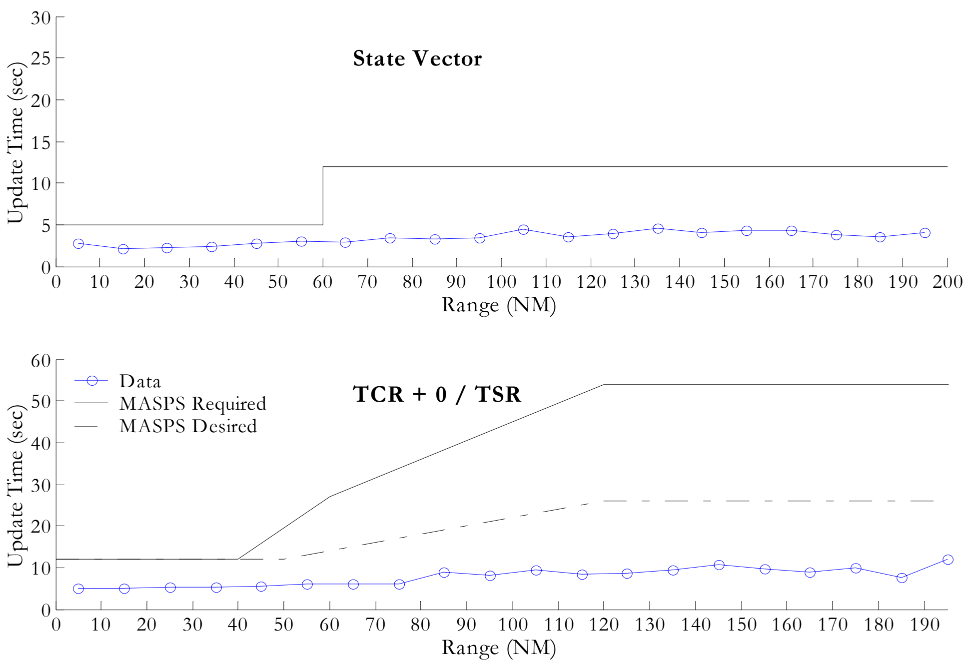


Figure K-34: **Ground Receiver Receiving A3 Transmitters**

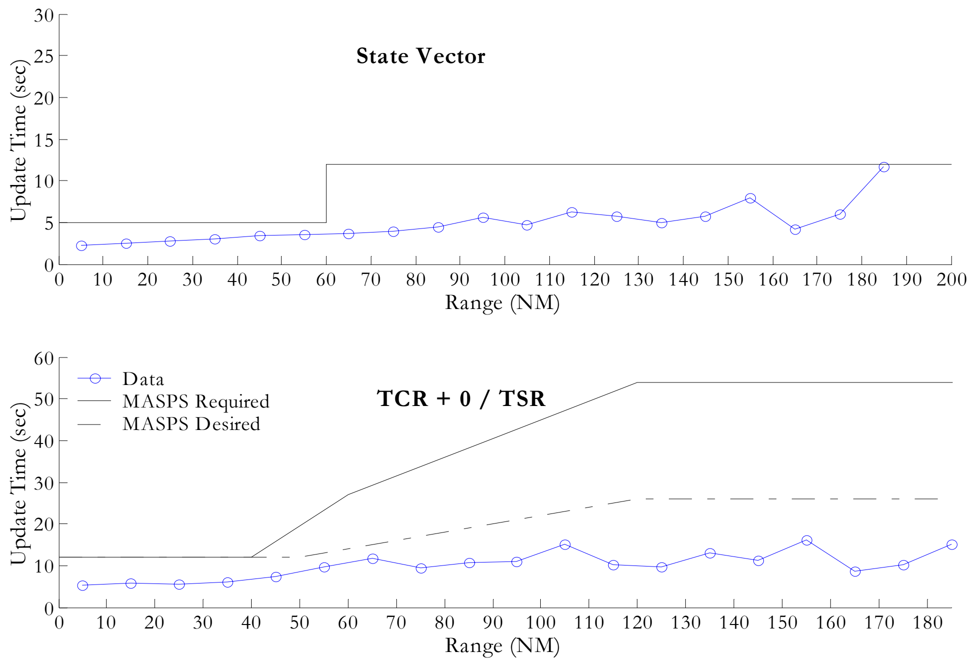


Figure K-35: **Ground Receiver Receiving A2 Transmitters**

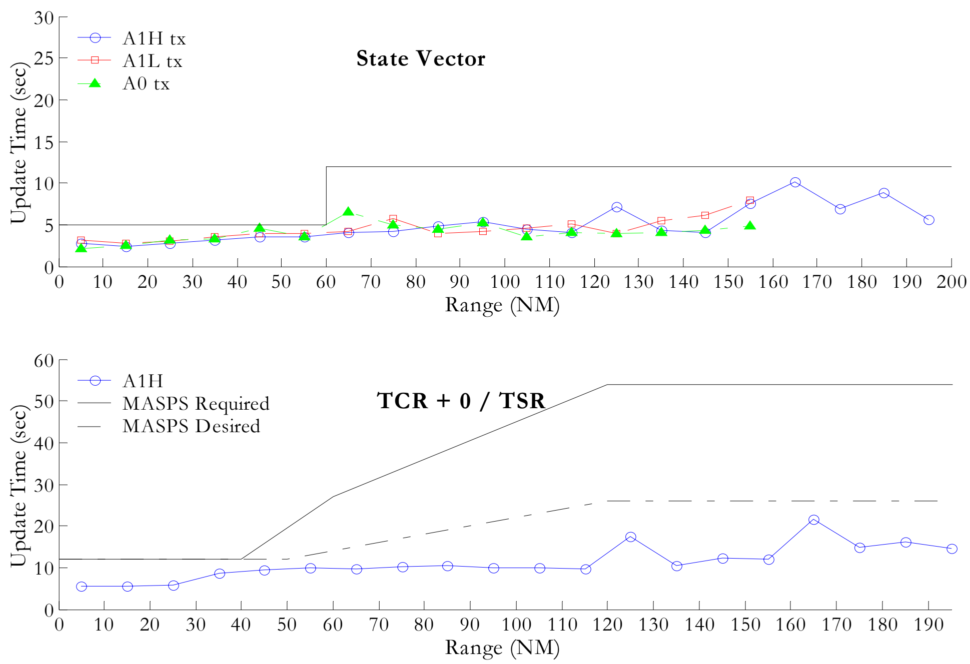


Figure K-36: **Ground Receiver Receiving A1 and A0 Transmitters**

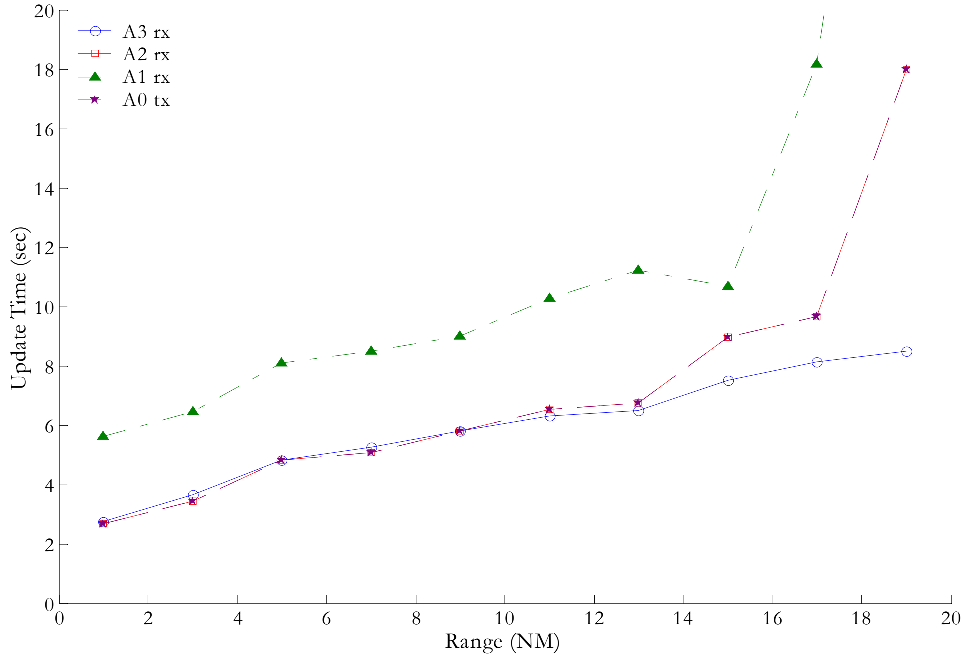


Figure K-37: **State Vector Updates from Ground Vehicle Transmitters for all Types of Receivers at 2000 feet Altitude**

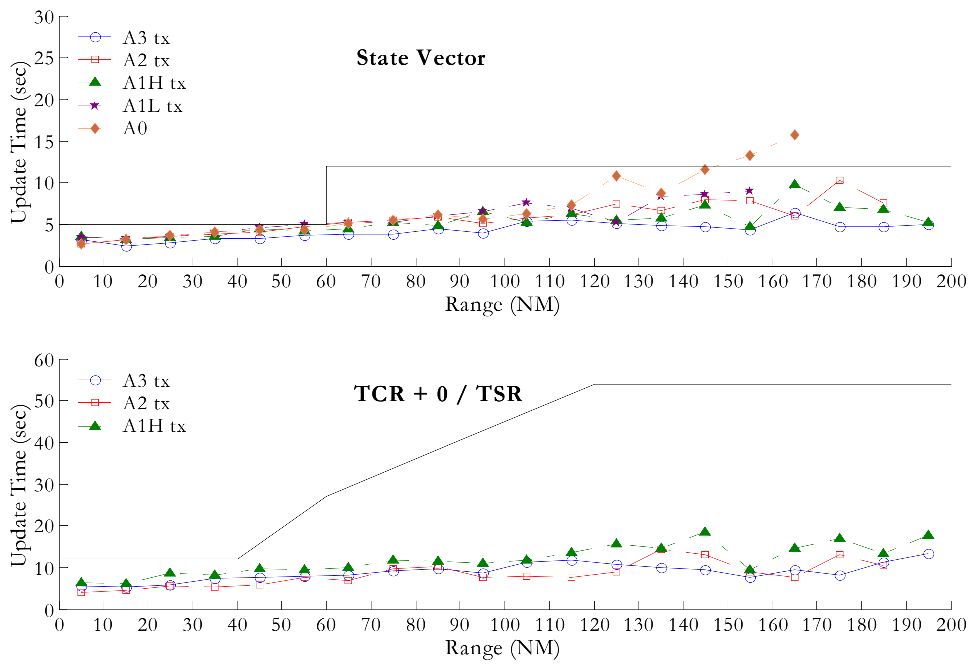


Figure K-38: **Ground Receiver in LA with Sectorized Antenna with a 10 kW TACAN at 980 MHz located 1000' away**

Recall that the LA 2020 scenario includes 2694 aircraft and 500 ground vehicles transmitting on UAT. In addition, a baseline Link 16 scenario is also included as co-channel interference.

The results for LA 2020 shown in Figure K-13 through Figure K-38 may be summarized as follows:

- ADS-B MASPS air-air requirements and desired criteria are met for all aircraft equipage transmit-receive pairs for both state vector and intent update rates at all ranges specified by the MASPS.
- The Eurocontrol extension to 150 NM for A3 class equipage is only met for LA 2020 at the 95% level out to 130-135 NM, but is met to 150 NM at the 88-93% level.
- Air-ground update requirements are met to 150 NM for all aircraft equipages. An excursion was run for the possibility of a 980 MHz DME/TACAN co-located with the ground receiver. Even in the presence of a 5 kw TACAN at 980 MHz located 1000 feet away, a sectorized antenna allows the update requirements to be met for all aircraft equipages to 150 NM.
- Results are presented for updates of ground vehicles in an aircraft on approach. We know of no specified requirements for this situation.

K.3.3 Core Europe

Two cases were considered for Core Europe: a current scenario and one which focuses on 2015. The reason these two cases were considered is that the operation of UAT in Core Europe 2015 is based on the premise that the existing on-channel DME/TACANs will be moved from 978 MHz to other available frequencies. Therefore, the future scenario assumes that there will be no DME/TACANs on 978 MHz, but that all existing and planned DME/TACANs at 979 MHz will be operational and running at full allowed power levels, no matter how close they are to one another. This condition was chosen in order to provide a conservative estimate of the DME/TACAN interference environment.

The current Core Europe scenario was also considered, in order to provide an estimate of UAT performance in the transitional period until the current transmitters at 978 MHz could be moved to other frequencies. For both scenarios, two sub-cases were analyzed: worst-case traffic density (over the center of the scenario at Brussels) and worst-case DME/TACAN environment (location selected to provide the highest interference from DME/TACANs).

For the Core Europe 2015 scenario, the distributions and assumptions made were taken directly from the Eurocontrol document entitled “High-Density 2015 European Traffic Distributions for Simulation,” dated August 17, 1999. This scenario is fairly well-defined and straightforward to apply. This scenario includes a total of 2091 aircraft (both airborne and ground) and 500 ground vehicles, and is based on the following assumptions:

- There are five major TMAs (Brussels, Amsterdam, London, Paris, and Frankfurt), each of which is characterized by:
  - The inner region (12 NM radius) contains 29 aircraft at lower altitudes,
  - The outer region (50 NM radius) contains 103 aircraft at mid to higher altitudes.
  - There are assumed to be 25 aircraft on the ground, within a 5 NM radius, plus another 25 aircraft randomly distributed throughout the entire scenario area.

- There are assumed to be 100 ground vehicles equipped with transmit-only UAT equipment.

- These aircraft are assumed to be symmetrically distributed rotationally, and the aircraft in an altitude band are assumed to be uniformly distributed throughout the band. However, all aircraft in the same band are assumed to be traveling at the same band-dependent velocity.

- Superimposed over these aircraft is a set of airborne en route aircraft, which are distributed over a circle of radius 300 NM. These aircraft are distributed over four altitude bands, ranging from low to upper altitudes. They also travel at velocities that are altitude band dependent.

- As in the LA Basin 2020 scenario, for the Core Europe 2015 scenario all aircraft are assumed to be ADS-B equipped. The equipage levels have been adjusted to be:
  - 30 % A3
  - 30% A2
  - 30% A1
  - 10% A0

Aircraft equipage is assigned according to altitude. The lower percentages of A0 and A1 aircraft than those found in the LA Basin scenarios reflect differences in operating conditions and rules in European airspace.

The current Core Europe scenario is defined by using the same algorithm for generating the aircraft as for Core Europe 2015, but reducing the total number of aircraft proportionally, to reflect today's maximum values for the number of aircraft in operation.

The two geographical areas which underlie the scenarios discussed above (LA Basin and Core Europe) correspond to very different types of situations for an aircraft to operate in, and thus should provide two diverse environments for evaluation. The LA Basin scenario contains only about 14% of all airborne aircraft at altitudes above 10000 ft, while the Core Europe scenario has around 60% above 10000 ft. Thus, there will be vastly different numbers of aircraft in view for the two scenarios. Additionally, the aircraft density distributions are also quite different, which will place different stresses on the data link systems.

K.3.3.1 The rest is TBD.

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